Brief Communication: Foramen Magnum–Carotid Foramina Relationship: Is It Useful for Species Designation?

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ABSTRACT The anterior placement of the foramen magnum is often used to indicate bipedalism and therefore to distinguish hominid from nonhominid fossils. Often, only fragmentary cranial remains are found, and the placement of the foramen magnum must be determined by its relationship to another landmark. The purpose of this study was to test if hominid crania could be distinguished from nonhominid crania based on the relationship between the foramen magnum and the carotid foramina, and therefore to determine if the carotid foramina can be used to determine the anteriorness of the foramen magnum. The samples consisted of 16 modern human crania and 19 modern chimpanzee (*Pan troglodytes*) crania. Linear measurements were taken of (1) the distance from the anterior border of the foramen magnum to a chord connecting the carotid foramina and (2) total cranial length. An index of the distance of the foramen magnum from the bicarotid chord as a proportion of total cranial length was calculated to control for differences due to body size. Results indicate that on average, human crania can be distinguished from chimpanzee crania by using either (1) the distance of the foramen magnum from the bicarotid chord as a linear measurement or (2) this linear measurement as a proportion of total cranial length. Both measures are significantly smaller in the human sample; however, there was considerable overlap between species, indicating that the distance of the foramen magnum from the bicarotid chord is not a certain indicator for individual specimens. Am J Phys Anthropol 110:467–471, 1999.

Because of the fragmentary nature of fossil remains, it is necessary to obtain as much information as possible from each specimen. This includes determining the relationship between as many different skeletal landmarks as possible. The purpose of this study was to test the hypothesis that human crania could be distinguished from chimpanzee crania based on the position of the foramen magnum relative to a bicarotid chord and therefore to determine if the carotid foramina are useful landmarks for detecting the anterior migration of the foramen magnum found in hominids. An assumption is that the shorter the distance between these two landmarks, the more anterior the foramen magnum.

In hominids, the foramen magnum is reported to be situated more anteriorly compared to nonhuman primates, and its placement is often used as a diagnostic trait for the hominid taxa (Biegert, 1963; Dean & Wood, 1981; Le Gros Clark, 1955; Luboga and Wood, 1990; White et al., 1994). Several studies have noted a forward placement of the foramen magnum in hominids compared

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to other primates, but give no quantitative data (Le Gros Clark, 1955, 1971; Dean, 1988; Biegert, 1963; Tobias, 1991). Other studies have quantitatively examined the position of the foramen magnum relative to different landmarks. These landmarks include the foramen cecum, subnasale, glabella (Luboga and Wood, 1990), spheno-occipital synchondrosis, bi-infratemporal fossa, a biauricular line (Dean and Wood, 1981, 1982), a biauricular band (Senyurek, 1938) and a bitympanic line (Dean, 1988; Aiello and Dean, 1990). All of these studies indicate that there are no significant differences in the relationship between the foramen magnum and the specific landmarks within a single species but that there are significant differences in the relationship between species, with modern humans having a more anteriorly placed foramen magnum compared to other primates.

Previous studies have also examined the position of the foramen magnum as a proportion of total cranial length and results indicate that in hominids, the foramen magnum is more anterior relative to total cranial length compared to other primates (Senyurek, 1938; Schultz, 1942; Le Gros Clark, 1955; Ashton and Zuckerman, 1952, 1956; Adams and Moore, 1975).

Recently, White et al. (1994) reported on the finding of a new species of hominid, *Australopithecus ramidus.* Cranial remains of *A. ramidus* were described as having a "strikingly chimpanzee-like morphology" (White et al., 1994, p. 310). An occipital fragment (ARA-VP-1/500) was described as having a foramen magnum that is bisected by a bicarotid chord. This finding was interpreted as indicating a more anterior placement of the foramen magnum, which was interpreted as suggesting hominid affinities. Based on this and other features, the specimen was included in the hominid genus of *Australopithecus.* The relationship between the foramen magnum and the carotid foramina, to indicate anterior placement of the foramen magnum, was untested. Subsequently, *A. ramidus* has been renamed *Ardipithecus ramidus* (White et al., 1995) and its hominid affinity is unclear. The impetus for this study was to test the initial assumption of White et al. (1994) that the carotid foramina are useful landmarks for determining anterior placement of the foramen magnum and therefore can be used to distinguish hominids from nonhominids.

MATERIALS AND METHODS

Materials

The sample included 19 adult chimpanzee (*Pan troglodytes*) crania and 16 adult modern human (*Homo sapiens sapiens*) crania. Adult status was based on complete eruption of the third permanent molar. The modern human crania consisted of biological supply specimens, probably from southern Asia, and curated in the teaching collection of the Department of Anthropology at Arizona State University (ASU). The chimpanzee sample consisted of crania of captive chimpanzees. Fourteen crania were selected from the Primate Foundation of Arizona skeletal collection. The remaining five crania are part of the ASU skeletal teaching collection. Neither sample was divided according to sex since previous studies have found no sexual dimorphism in the position of the foramen magnum (Ashton and Zuckerman, 1952; Moore et al., 1973; Adams and Moore, 1975; Luboga and Wood, 1990).

Methods

The following landmarks were located on the crania: a bicarotid chord (BCC), basion (BS), glabella (GL) and opisthocranion (OPN) (Fig. 1). The bicarotid chord is a line connecting the center of the carotid foramina (CC) (White et al., 1994), the remaining three landmarks are standard landmarks (see Bass, 1987 for definitions). Linear measurements of BS-BCC and OPN-GL were taken directly from the basicranium and were recorded to the nearest 0.1 cm. Measurements were taken twice, several days apart. The largest intra-observer error was 0.1 cm and the difference between sample averages was less than 0.02 cm. An index of BS-BCC $\times$ 100/OPN-GL was calculated to represent the distance of the foramen magnum from the bicarotid chord as a proportion of total cranial length. The measurement OPN-GL is isometric relative to body size (Luboga and Wood, 1990) and was used to control for differences in BS-BCC length due to body size.

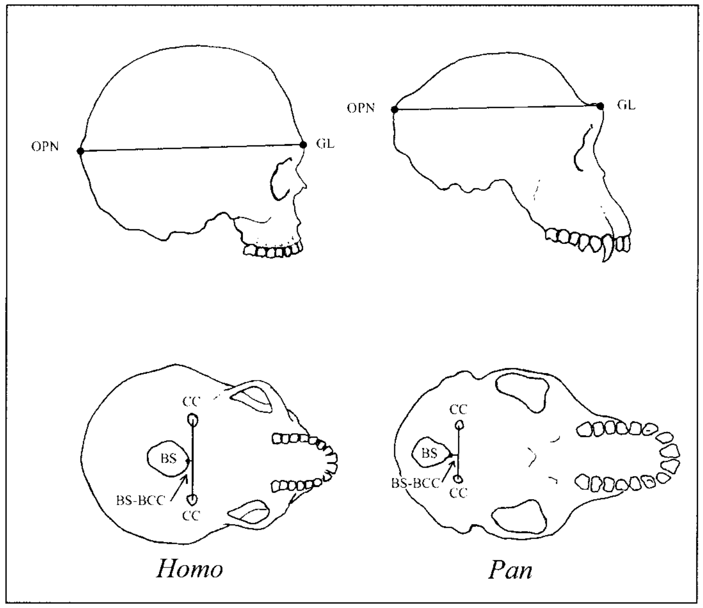

Fig. 1. Diagram of cranial landmarks and measurements taken (OPN, opisthocranion; GL, glabella; CC, carotid foramina; BS, basion; OPN-GL, cranial length; BS-BCC, distance of basion to bicarotid chord).

Comparison of the means of the linear measurements and the index was made using a one-tailed Student's t-test, $\alpha < 0.05$. Because of the small sample size, a more conservative nonparametric statistic (Mann-Whitney test) was also calculated. In addition, a Pearson's correlation coefficient was calculated for BS-BCC and OPN-GL for both the human and the chimpanzee sample.

RESULTS

The range, mean, and standard deviation of the linear measurements (BS-BCC and OPN-GL) and the calculated index (BS-BCC $\times$ 100/OPN-GL) are given in Figure 2. The results and the associated p-value are given in Table 1. The Pearson's correlation coefficient was $r = 0.134$ for the human sample and $r = -0.209$ for the chimpanzee sample.

The mean BS-BCC length was significantly smaller for the human sample (x = 0.62) than for the chimpanzee sample (x = 0.85), indicating less distance between foramen magnum and the bicarotid chord for the human sample and therefore a more anterior foramen magnum. The mean total cranial length (OPN-GL) was significantly smaller for the chimpanzee sample (x = 13.88) than for the human sample (x = 17.17). The mean index (BS-BCC $\times$ 100/OPN-GL) was significantly smaller for the human sample (x = 3.60) than for the chimpanzee sample (x = 6.14). Overlap occurred between the species for the ranges of BS-BCC, and the calculated index with the ranges for the chimpanzee sample being greater and the human sample range fitting within the chimpanzee range.

DISCUSSION

Although it is not disputed that hominids can be distinguished from nonhominids based on their anterior placement of the foramen magnum, the purpose of this study was to determine if such a distinction can be made based on the relationship between the carotid foramina and the foramen magnum.

The small correlation coefficients indicate little, if any, relationship between the distance of the foramen magnum from the bicarotid chord (BS-BCC) and total cranial length (OPN-GL). The comparisons of the two species means showed that on average the distance between the foramen magnum and the bicarotid chord (BS-BCC), and this distance as a proportion of the total cranial length (BS-BCC $\times$ 100/OPN-GL), were significantly smaller for the modern human sample. This result indicates that the foramen magnum

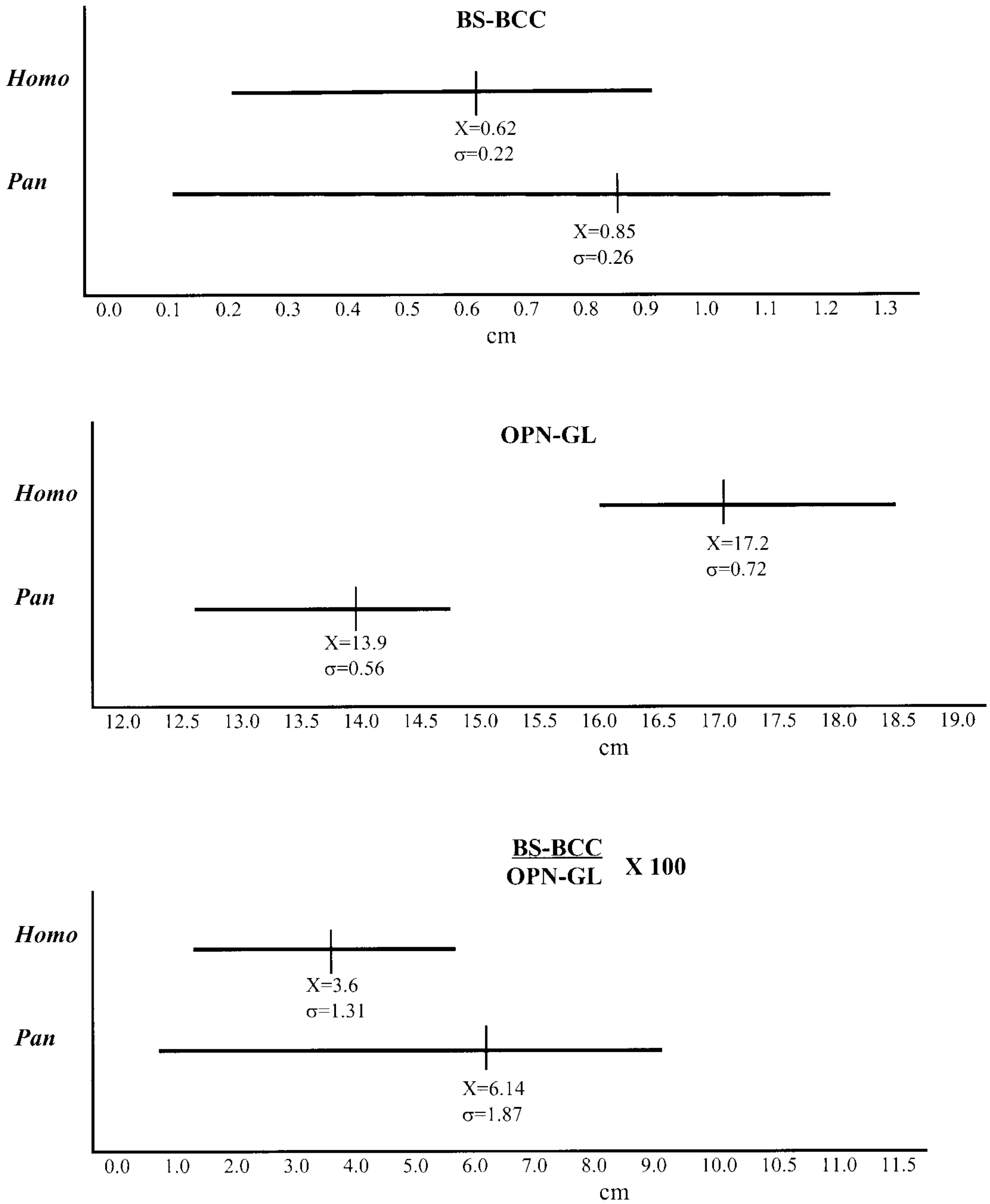

Fig. 2. Range, mean and standard deviation of linear measurements and calculated index.

is more anterior relative to the bicarotid chord for the human sample. The phrase "on average" must be emphasized, since there was considerable overlap of BS-BCC measurements between species and the smallest BS-BCC (and therefore the most anterior foramen magnum) was found on a chimpanzee specimen (BS-BCC = 0.1 cm).

These results indicate that: (1) on average, human crania can be distinguished

TABLE 1. Results of metrical comparisons of human and chimpanzee crania

Measurement	Student's T-value	Mann-Whitney z-value
BS-BCC	$T = 2.82$, p-value < 0.005	$z = -5.96$, p-value < 0.01
OPN-GL	$T = 26.97$, p-value < 0.0005	$z = 5.03$, p-value < 0.0003
BS-BCC × 100 OPN-GL	$T = 13.72$, p-value < 0.0005	$z = -4.01$, p-value < 0.0003

from chimpanzee crania by using the distance of the foramen magnum from the bicarotid chord (BS-BCC) either as a linear measurement or as a proportion of total cranial length; (2) the smaller distance between the foramen magnum and the bicarotid chord found in the human sample indicates that the carotid foramina are useful landmarks for determining anterior placement of the foramen magnum; (3) the significant differences found in the calculated index and the small correlation coefficient between BS-BCC and OPN-GL indicates that the differences in the BS-BCC length are not simply due to differences in body size; and (4) when using the distance of the foramen magnum from the bicarotid chord to distinguish a human cranium from a chimpanzee cranium, caution should be used as there was considerable overlap between species.

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